INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0370

Crossflow Filtration

Tanks Focus Area

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DISCLAIMER

INNOVATIVE TECHNOLOGY
Summary Report

Crossflow Filtration

OST Reference # 350

Tanks Focus Area

Demonstrated at
U.S. Department of Energy
Savannah River Site, Aiken, South Carolina
Hanford Site, Richland, Washington
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho
Oak Ridge National Laboratory, Oak Ridge, Tennessee

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

Technology Summary

Within the DOE complex, 335 underground storage tanks have been used to process and store hazardous and radioactive mixed waste generated from weapon materials production and manufacturing. Collectively, these tanks hold over 90 million gallons of high-level and low-level radioactive waste in the form of sludge, saltcake, and supernatant liquid. Very little has been treated and/or disposed of in final form.

Solid-liquid separation technologies are required for a variety of tank waste remediation activities. For example, fine particles suspended in liquid waste need to be removed because they carry excess radioactivity into the low activity waste and can interfere with treatment processes such as ion-exchange or solvent extraction. Solid-liquid separation is also needed to remove solids from sludge wash liquids. Tank waste sludges will undergo water-washing and caustic leaching prior to immobilization and disposal as high-level waste. Examples of separation technologies under consideration for these applications include crossflow filtration, backwashable-cartridge filtration, in-tank settling, hydrocyclone, and counter-current decanting.

Conventional dead-end filtration methods operate with the feed (slurry) flow in the same direction as the permeate flow (i.e., into the filtration media). An alternative method is to recirculate the slurry and thereby maintain a high velocity of flow parallel, or crossflow, to the filter media surface. This helps minimize particle build-up on the filter as shown in Figure 1.

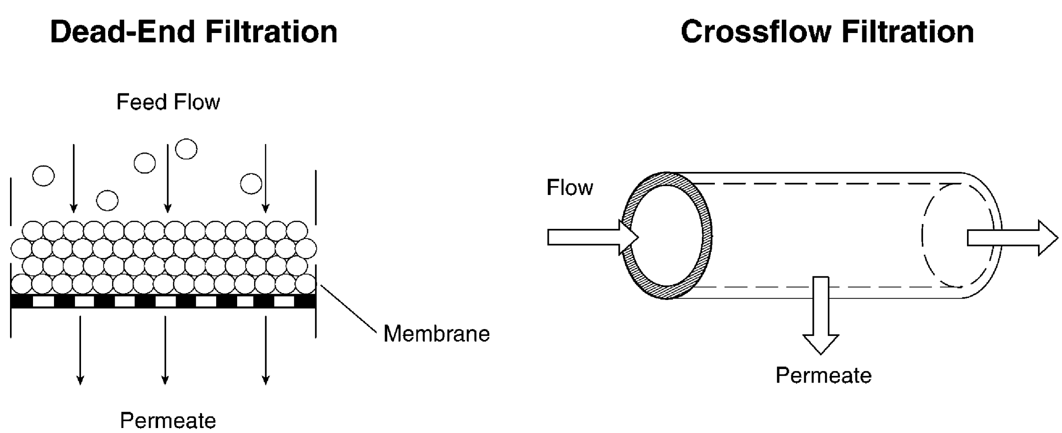

Figure 1. Comparison of conventional “dead-end” filtration with crossflow filtration.

Demonstration Summary

The following demonstrations of crossflow filtration for application to DOE tank waste remediation problems have been performed or are planned in the time-frames indicated:

Hot cell demonstration with actual Hanford waste	1996-97
Radioactive Demonstrations at INEEL	1997-98
Full scale demonstration at Oak Ridge with actual waste	1998-99

In addition, other demonstrations, engineering analyses, and laboratory tests have been performed by researchers at Savannah River Site and Oak Ridge.

In-tank gravity settling is the current baseline at Hanford and Savannah River Site for solid-liquid separation after sludge washing. Crossflow filtration is a leading candidate (and in certain cases becoming the new baseline) for pretreatment of tank waste at DOE sites because it can handle a wide variety of waste types, can be maintained remotely, and materials of construction are compatible with the wastes. It is useful for removing particulates from liquid wastes and for concentrating solids after sludge washing.

A cost comparison performed at Hanford estimated a $268 million advantage for crossflow filtration compared to gravity settling for treatment of sludge wash liquids. The analysis also showed that a properly designed pretreatment system using crossflow filtration would significantly reduce the amount of caustic, water, and other chemicals necessary for pretreatment (Raytheon/BNFL, 1995).

Crossflow filtration is considered a leading alternative for treatment of Hanford site wastes based on bench-scale demonstrations with slurries from five different tanks. Crossflow filtration was found to remove solids effectively, as judged by filtrate clarity and radiochemical analysis. Nominal filtrate flux was 0.05 gpm/ft^2 which corresponds to a 1,140-ft^2 filter requirement to treat all of Hanford's waste. By comparison, a 430 ft^2 crossflow filtration system is installed at Savannah River Site for treating supernate.

Solid-Liquid separation will be needed at the Idaho National Engineering and Environmental Laboratory to clarify acidic liquid waste prior to radionuclide separations. Demonstrations conducted in 1997 and 1998 show that crossflow is effective at removing solids from acidic waste from tanks and dissolved calcine. This will help the site attain substantial cost savings during future waste processing due to high level waste volume reduction.

Waste retrieved from inactive tanks at Oak Ridge will be consolidated in the Melton Valley Storage Tanks for treatment and subsequent disposal Effective solid-liquid separation is needed at Oak Ridge to clarify supernate and to segregate and concentrate sludges. This reduces the overall volume of waste for disposal, reduces the cost of treatment and disposal, and reduces hazards to workers who manage the waste.

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Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference # for crossflow filtration is 350.

SECTION 2

TECHNOLOGY DESCRIPTION

Technology Description

Conventional dead-end filtration methods operate with the slurry (feed) flow in the same direction as the permeate flow (i.e., into the filtration media). The disadvantages of using such filters include:

- filtrate flow (flux) decreases rapidly as particle layers accumulate on the filter,
- continuous particle layer build-up results in low overall flow rates,
- frequent cleaning or change out of filters is required,
- filter aids are often needed which can significantly increase waste volume and disposal costs.

An alternative method is to recirculate the slurry, thereby maintaining a high velocity of flow parallel, or crossflow, to the filter media surface. The crossflow principle uses shear forces created by flow across the membrane to keep particle build-up to a minimum. While crossflow filtration does not completely eliminate the particle boundary layer, it does lead to higher flow rates as shown in Figure 2.

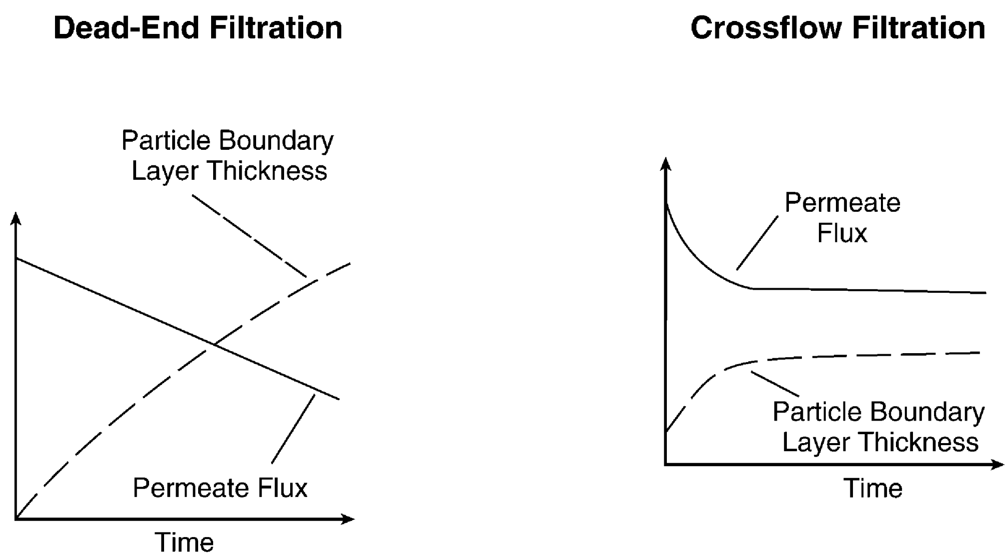

Figure 2. Comparison of flux rates and particle boundary layer thickness.

Another advantage of crossflow filtration is that it can be operated continuously, does not require frequent change-out, and can concentrate slurries to very high solids content.

Based upon engineering analysis and testing with actual wastes, crossflow filtration was selected as baseline for treatment of liquid waste in tanks at Savannah River Site. Subsequent evaluations and demonstrations have built upon this knowledge and experience, transferring experimental demonstration techniques and equipment, namely the cell unit filter, to the other DOE tank sites.

Bench-scale, crossflow filtration units have been installed in shielded hot cells at each of the tank sites to facilitate testing with actual radioactive wastes. Capabilities of the cell unit filter are as follows:

- 6 in. to 18 in. active filter length - approximately 1 to 3 ft^2 filter area,
- axial velocity may be controlled between 3 and 10 ft/s,
- transmembrane pressure from 5 to ~50 psig,
- required volume for testing is ~800 ml,

- temperature is controlled by a cooling jacket on the slurry reservoir,
- back-pulsing may be conducted as required.

A process schematic of the cell unit filter used for testing is provided in Appendix B.

A demonstration was conducted at Hanford using actual wastes from five different tanks to evaluate the effectiveness of crossflow filtration and provide data useful for design of a full scale filtration system. Transmembrane pressures were varied from 5 to 50- psig and recirculation flow rates (axial velocities) were varied from 3 to 9 ft/s in order to observe the effect on filtrate flux due to variations in these parameters. Tests were run at three different solids concentrations to reflect conditions expected during waste retrieval (1.5 wt %), sludge washing (8 wt %), and supernate treatment (0.05 wt %). Effectiveness was determined by the nominal filtrate flux attained as well as the extent of solids removal from the filtrate as measured by transuranics and strontium removal. A cell unit filter installed in a Hanford hot cell was used for the demonstration which is essentially bench scale relative to the filter size required to treat all Hanford waste.

At Idaho, demonstrations are being conducted with a cell unit filter system installed in an INEEL hot cell. Similar to the Hanford demonstration, a matrix of test parameters is being used to observe the effects of transmembrane pressure and axial flow rate on filtrate flux. However, the INEEL wastes are different in that they are acidic, requiring special materials of construction (Hastelloy), and they have relatively low solids content. Both dissolved calcine and liquid sodium bearing wastes are being tested. Since the total volume of waste at INEEL is less than the other sites, a cell unit filter demonstration is more like a pilot scale test of the process and the data can be used to scale up directly to full scale plant design.

A full scale demonstration of crossflow filtration using actual waste at Oak Ridge Reservation is planned to begin in the fall of 1998. To prepare for this, bench scale tests were run at Savannah River using simulated Oak Ridge wastes and two different types of sintered metal crossflow filters. The results were used to specify commercially available filter elements in the design of the full scale demonstration unit. Radioactive tests were also run at Oak Ridge using a cell unit filter system using samples of waste to be transferred to the Melton Valley Storage Tanks for eventual treatment and disposal. Special requirements for Oak Ridge include the fact that the solids are expected to contain relatively large chunks of concrete from the tank walls which may require a roughing filter to prevent the crossflow tubes from clogging.

PERFORMANCE

Performance

Bench scale crossflow demonstrations have been performed at several DOE tank waste sites. These demonstrations have produced performance data showing the relationship between key operating parameters and crossflow filtration production rate, or filtrate flux (gallons per minute filtrate per square foot of filter area).

Results from testing with Hanford waste appear in Figure 3. For a slurry with relatively high solids concentration (8 wt %), filtrate flux increased with transmembrane pressure but leveled-off at about 0.05 gpm/ft^2. When measured versus axial velocity, filtrate flux increased greatly at higher slurry flow rates. This indicates that faster slurry flow through the interior of the filter reduces filter cake thickness and increases filtrate production rate.

At a nominal filtrate flux of 0.05 gpm/ft^2, the filtration capacity required to treat all Hanford supernate and sludge wash solutions would be about 1,140 ft^2 of filter material yielding an average 57 gpm filtrate flow rate (Orme, 1994). By comparison, the Savannah River Site has a 432 ft^2 crossflow filtration system for treating supernate. The baseline for sludge wash liquids at both sites is gravity settling.

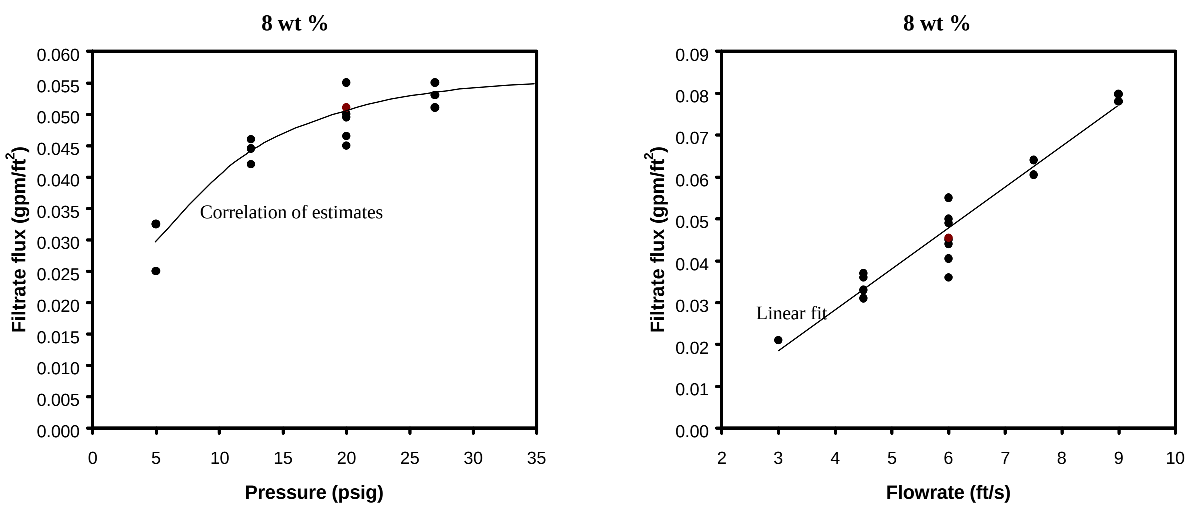

Figure 3. Tank B-110: Filtrate flux as a function of transmembrane pressure and axial flowrate.

Tests with sodium bearing waste (SBW) at the Idaho National Engineering and Environmental Laboratory have produced somewhat different results. INEEL waste is acidic and has a much lower solids concentration (e.g. 0.20 to 0.25 wt % for tank WM-183). Testing was performed in a cell unit filter fitted with a 0.5 Tm Hastelloy filter element. Results appear in Figure 4 (Tripp and Wade, 1997).

The results show filtrate flux increasing linearly with transmembrane pressure. Note that filtrate production rates more than double those observed in the Hanford tests were achieved. Interestingly, when plotted versus axial flowrate, filtrate flux appears to decrease with increasing flow rate through the filter tube, leveling-off at higher axial flow rates. This indicates that at low solids concentrations, factors other than filter cake thickness control filtration rate.

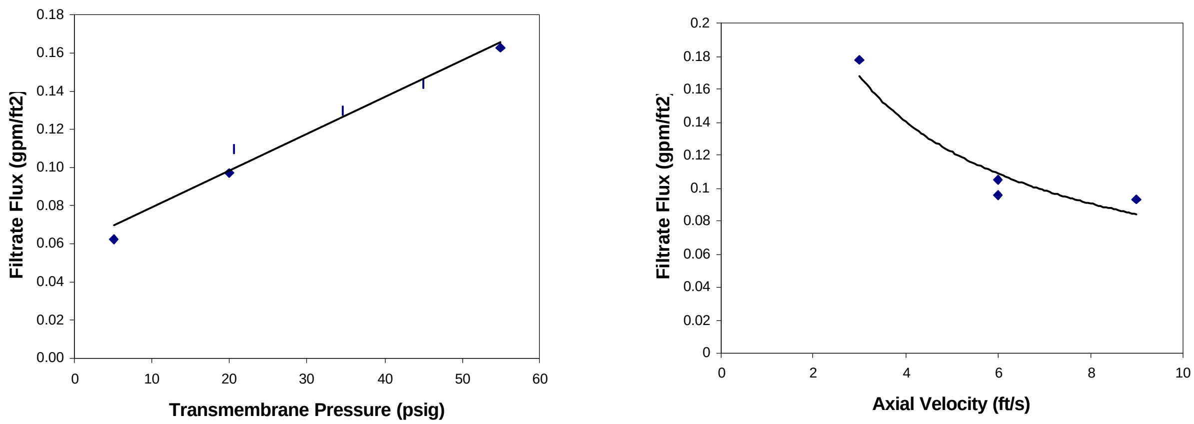

Figure 4. Tank WM-183: Filtrate flux as a function of transmembrane pressure and axial flowrate.

Tests were also run at the Savannah River Site with simulated Oak Ridge tank waste to identify appropriate filter media, process conditions, and overall filtration rate for treating Oak Ridge tank waste (McCabe, 1996). A test matrix similar to those employed for the Hanford and INEEL demonstrations was carried out using simulated waste at 0.1, 1, 5, and 15 wt % solids concentrations.

As shown in Figure 5, the results for the 1 wt % slurry test indicate that filtrate flux is proportional to transmembrane pressure producing about 0.10 gpm/ft2 filtrate flow at typical operating pressures of 30-40 psig. Filtrate flux does not appear to correlate with axial flow at this solids concentration indicating that mechanisms other than filter cake thickness may be controlling filtration rate.

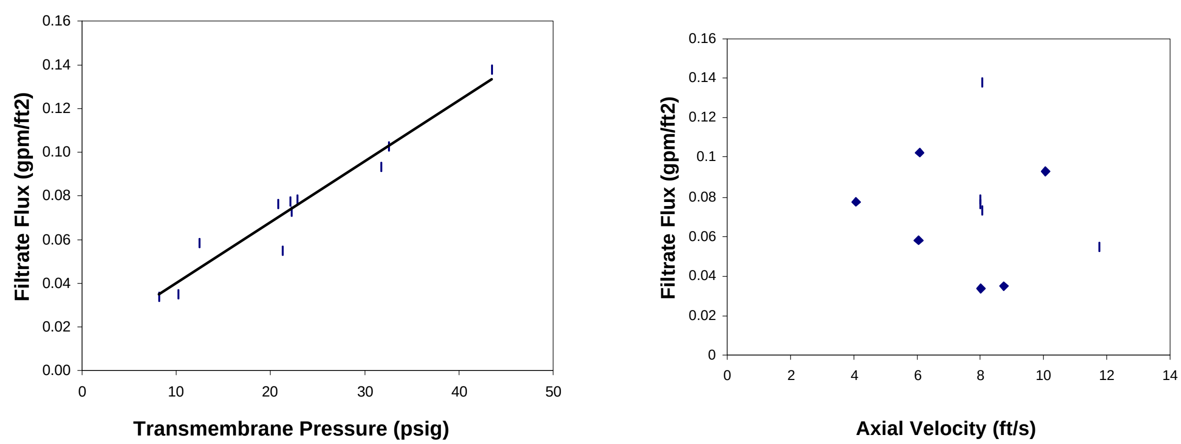

Figure 5. Filtrate flux relationship to transmembrane pressure and axial velocity for simulated Oak Ridge waste.

Filtration Effectiveness

Crossflow filtration effectively removed solids from liquid in the five radioactive Hanford Site tank wastes tested (S-107, C-106, C-107, B-110, and U-110), as judged by filtrate clarity and radiochemical analysis (Geeting and Reynolds, 1996 and 1997). The transuranic (TRU) elements, most of which are alpha emitters, are typically insoluble in alkaline wastes and can thus act as radioactive tracers for measuring solids removal. Total alpha analysis of the feed and filtrates is summarized in Table 1.

Table 1. Total alpha analysis

Hanford tank number	Sample solids (wt %)	Alpha radiation in feed (nCi/g)	Alpha radiation in filtrate (nCi/ml)	Decontamination factor[1]
S-107	0.05	1.3[2]	<0.093	14
S-107	1.5	38	<0.093	>410
S-107	8	215	<0.087	>2,500
C-106	0.05	1.9[2]	0.06	32
C-106	1.5	58[2]	10[3]	6
C-106	8	310	68[3]	5
C-107	0.05	5.3	0.13	41
C-107	1.5	210	0.0087	24,000
C-107	8	1,700	0.023	74,000
B-110	0.05	0.4[2]	0.0041	98
B-110	1.5	11	<0.003	>3,700
B-110	8	63	<0.03	>2,100
U-110	0.05	0.3[2]	0.017	18
U-110	1.5	9	<0.003	>3,000
U-110	7.5	<20	0.0094	<2,100

(1) Decontamination factors converted from volumetric basis (nCi/ml) to mass basis (nCi/g) by applying specific gravity of 1.0.
(2) Values reported were calculated based on dilution.
(3) Alpha activity in the filtrate is believed to be due to plutonium complexation with carbonate.

Strontium is also insoluble in alkaline waste and behaves similarly to the TRUs. If the filtrates from these tests were immobilized in a glass matrix, the resulting TRU and ^{90}Sr activity in most cases would fall within Hanford low-activity waste (LAW) limits of 100 nCi/g TRU and 20 uCi/ml ^{90}Sr, as shown in Table 2. ^{90}Sr activity is 10 to 100 times lower than the LAW glass limit for all samples and TRU activity is well below limits for all but the 1.5 and 8 wt % C-106 tests.

Table 2. Predicted activity in low-activity waste glass resulting from immobilizing filtrate[1]

Hanford tank number	Sample solids (wt %)	Transuranic activity (nCi/g)	^{90}Sr activity (uCi/ml)
C-106	0.05	13	0.23
C-106	1.5	**181**[2]	0.89
C-106	8	**391**[2]	1.18
C-107	0.05	37	2.09
C-107	1.5	2.0	0.65
C-107	8	2.0	0.11
B-110	0.05	0.9	0.47
B-110	1.5	0.10	0.98
B-110	8	0.19	0.22
U-110	0.05	4	0.43
U-110	1.5	0.27	0.02
U-110	7.5	0.24	0.23

(1) Based on a typical glass density of 2.6 g/cm3 and 20 wt % Na_2O as the limiting oxide in the low-level waste glass.
(2) Activity exceeds low-activity waste glass limit of 100 nCi/g.

Subsequent analyses of C-106 indicate that the TRU activity in the filtrate was most likely due to soluble plutonium caused by complexation with carbonate. Thus, crossflow filtration removed the insoluble activity, while the soluble plutonium species passed through as expected. Radionuclide de-complexation may be required prior to any type of solid-liquid separation for tank wastes like C-106.

Effectiveness of crossflow filtration for clarifying Oak Ridge tank wastes was assessed based on testing at Savannah River Site with simulated waste. Turbidity of the filtrates was measured and results are presented in Table 3. Particle size analysis of each of the slurry samples showed 10 vol % of particles with diameter less than 1.3 Tm for all samples.

Table 3. Filtrate turbidity of filtrate in Oak Ridge simulant tests

Sample Description	Turbidity (NTU)
Dewater slurry to 19 wt %	0.45
15 wt % slurry, 0.5 Tm filter	0.43
5 wt % slurry, 0.5 Tm filter	0.09
1 wt % slurry, 0.5 Tm filter	0.08
0.1 wt % slurry, 0.5 Tm filter	0.80

Filtrates with turbidity values below 1.0 NTU are considered free of solids and are expected to be within limits for downstream processing at Oak Ridge.

Dead-end filtration tests

Dead-end filtration tests were also carried out with simulated Oak Ridge waste. Filter aids were required to maintain filter cake porosity and filtrate flow. Diatomaceous earth was added at 0.3 wt % to the 0.1 wt % slurry. A 0.5 Tm sintered metal filter was used for testing.

The test was carried out for several load and backflush cycles. Filtrate flux was maintained at 0.12 gpm/ft^2 and pressure increased to a maximum of 30 psig for each cycle as the filter cake accumulated. Key results of the dead-end filtration test are shown in Table 4.

Table 4. Dead-end filtration results with Oak Ridge gunite simulant

Parameter	Value
Filtrate Flux	0.12 gpm/ft^2
Average Cycle Time	30 minutes
Filtrate Flow per cycle	3.6 gal/ft^2
Backflush volume	1.4 gal/ft^2
Net Filtrate Production	2.2 gal/ft^2
Net Flux	0.07 gpm/ft^2
Average Turbidity first 3 cycles	2.4 NTU

These results indicate that filtrate production can be significantly reduced (e.g. 40%), that solids content is increased significantly (4 X by weight), and that filtrate quality may be significantly reduced by utilizing dead-end filtration as opposed to crossflow. The high value for filtrate turbidity was attributed to carryover of fines from the diatomaceous earth.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

Crossflow filtration is applicable to many solid-liquid separation problems but is particularly well-suited to treatment of DOE tank waste.

- Crossflow limits filter cake build-up and generally eliminates the need for filter aids,
- Is preferable for solids that form low permeability filter cakes - like those found in DOE wastes,
- Is easily designed for remote maintenance - a significant advantage when treating highly radioactive wastes, and
- Can reduce chemical additions, waste volume, and cost of treating the waste.

Crossflow filtration thus is well suited for solid-liquid separation of waste in DOE tanks. This may explain why the Savannah River Site and West Valley Demonstration Project both have crossflow filtration in their waste treatment processes. Waste treatment processes at Hanford and Oak Ridge will be determined by private vendors. However, performance data from demonstrations at both sites will be available for use in their baseline selection processes. At INEEL, demonstration data will support conceptual design of a waste treatment facility provide input to an Environmental Impact Statement that will identify the preferred process for remediation of tank waste at INEEL.

Competing Technologies

Competing technologies include the following:

- Gravity settling
- Dead-end filtration (e.g. plate, deep bed, rotary drum)
- Centrifugation - hydrocyclone

Some of the disadvantages of the competing technologies include slow settling rates and poor solids compaction for gravity settling, filter cake resistance and large backflush volumes for dead-end filtration, and large forces needed to separate small particles in centrifugation.

An evaluation of solid-liquid separation needs for treating DOE tank waste and candidate solid-liquid separations processes for addressing those needs was performed in 1995 by the Tanks Focus Area (McCabe, 1995). Crossflow filtration was identified as applicable at all DOE tank waste sites.

An engineering trade study at Hanford evaluated a full set of candidate solid-liquid separation processes for pretreatment of Hanford waste (Raytheon/BNFL, 1994). Processes were evaluated for their ability to meet product specifications as well as past experience treating similar waste types. Crossflow and pneumatic hydropulse filtration were recommended as the best candidate technologies. Gravity settling was not selected because of concerns that particle attrition (due to in-tank processing) would result in slower settling rates. However, gravity settling remains the baseline for Hanford sludge washing, apparently because the process is simpler and can be done in-tank.

Solids concentration of sludge is an important parameter in the sizing and design of a sludge treatment process. Although higher solids concentration places higher duty on the filtration system, it reduces the amount of sodium hydroxide and wash water required. Work carried out at Oak Ridge and Savannah River (Fish and Landon, 1992) indicates that solids concentrations between 15 and 30 wt % are achievable with crossflow filtration.

Gravity settling typically produces lower solids concentrations. A full-scale sludge-washing demonstration with gravity settling at the Savannah River Site resulted in 13 wt % solids concentration (Ator, 1983; Eibling and Hamm, 1983; Hamm et al., 1983). In-tank processing is also a batch process which typically requires larger wash volumes and longer processing times than a continuous or semi-batch process that could be employed using crossflow filtration.

SECTION 5

COST

Cost Data

Cost/benefit information is available for selected applications of crossflow filtration within the DOE complex. Information presented here includes the application to Hanford sludge washing (anticipated to occur during Phase II of Hanford Privatization) and solid-liquid separation of slurries transferred to the Melton Valley Storage Tanks at Oak Ridge.

Cost data for the Hanford application were taken from a trade study prepared for the Tank Waste Remediation System Initial Pretreatment Module Project (Raytheon/BNFL, 1995). A two-stage crossflow filtration system was compared to in-tank sludge washing with gravity settling as the baseline technology.

The out-of-tank process is based on a two-stage, crossflow-filtration system. The first stage operates continuously to concentrate the sludge. The sludge is then transferred to a wash vessel where it is leached with caustic. After leaching, the sludge is processed through the second-stage filter where it is rinsed and dewatered.

In the in-tank process, all sludge-washing operations are performed sequentially with each batch of sludge remaining in the tank until all leaching and washing steps are complete. Eight double shell tanks operating in parallel are required to treat Hanford sludge at the desired rate.

Estimated capital and operating costs for the out-of-tank crossflow system are lower than those for the in-tank, gravity settling system probably because equipment and operating costs for eight modified double shell tanks are avoided. Material-balance calculations show that crossflow filtration is more efficient in chemical and water usage and, as a result, produces less low-level waste (LLW) glass and high-level waste (HLW) glass than in-tank processing. Crossflow filtration was estimated to save a total of $268 million, or about 10% of the total cost of sludge treatment. A summary appears in Table 5.

Table 5. Cost-Comparison Summary (in millions of dollars)

	In-Tank Settle/Decant	Out-of-Tank Crossflow	Difference
Capital cost	**151**	**92**	**59**
Operating and maintenance cost			
Mixer-pump replacements	26.7	3.3	23.4
Other pump replacements	18.9	4.7	14.2
Other equipment replacements	0.0	8.0	(8.0)
Operating personnel	69.3	16.8	52.5
Chemicals and water	8.7	6.9	1.8
Other	6.3	2.3	4.0
Subtotal	**129.9**	**42.0**	**87.9**
Waste-disposal cost			
High-level waste glass	1,997	1,909	88
Low-level waste glass	751	728	23
Used equipment burial	12	2	10
Subtotal	**2,760**	**2,639**	**121**
Total cost	**3,041**	**2,773**	**268**

Another example of estimated cost savings due to crossflow filtration is clarification of newly generated supernates at Oak Ridge. Liquid wastes from the Radiochemical Engineering Development Center (REDC) are responsible for 99% of the radioactivity and transuranic (TRU) content of the waste in Oak Ridge tanks.

The TRU components in this waste stream are present as particulates that are effectively removed by crossflow filtration. If transferred to the waste tanks, these solids would settle with other solids and create large volumes of TRU waste. By utilizing crossflow filtration, the annual TRU solids generation is reduced from 12,000 L to 40 L. The cost of treatment and disposal of TRU sludge is estimated at $140/L compared to non-TRU, solid low-level waste treatment and disposal cost of $13/L. Thus, the cost avoidance of implementing crossflow filtration at the Oak Ridge REDC is on the order of $1.5 M/yr (Robinson, 1997).

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

In general, waste in storage tanks at DOE sites are subject to a number of different regulations and regulatory authorities.

Most of the waste is high-level waste, derived from reprocessing of nuclear fuel, the disposal of which is governed by the Nuclear Regulatory Commission as required by the Nuclear Waste Policy Act of 1982. DOE is responsible for safe storage and treatment of the waste.

Certain materials used in reprocessing may be designated incidental waste and may be treated and disposed of on-site as low-level waste. The final waste form must meet NRC LLW disposal requirements. A performance assessment of the disposal site must demonstrate adequate protection of the public from radiation exposure.

The hazardous constituents of the waste are subject to regulation under the Resource Conservation and Recovery Act (RCRA). Most states are authorized to implement RCRA including permitting of hazardous waste treatment, storage, and disposal facilities.

Some of the tanks within the DOE complex were retired many years ago and contain legacy wastes. These may be subject to remediation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Waste storage and treatment facilities are also required to meet Clean Air Act and Clean Water Act requirements for airborne and liquid effluents. Requirements are typically implemented at the state or even local level for these statutes.

For treatment of tank waste, solid-liquid separation is important since it allows the waste to be separated into high activity and low activity fractions in order to minimize the volume of immobilized high level waste and dispose of the remainder as low level waste. However, the specific technology utilized to achieve separation is typically not specified in the regulations.

Treatment technologies are sometimes specified within compliance orders such as Hanford’s Tri-Party Agreement, but are often limited to immobilization technologies (waste forms) or emission control technologies. There are several examples where compliance orders allow separate decision processes to occur, such as evaluation of alternatives in an Environmental Impact Statement, through which a technical baseline is identified. Finally, engineering trade studies are used to select a specific technology to meet the baseline which is at a far more detailed level than regulatory authorities typically address.

Crossflow filtration can improve waste treatment performance and reduce the volume and cost of waste for disposal. A crossflow system can be designed to be completely remotely operated, thus increasing safety of the workers by requiring less frequent change-out and maintenance of filters.

SECTION 7

LESSONS LEARNED

Technology Considerations

Bench-scale demonstrations and cost analyses show that crossflow filtration is a leading candidate for solid/liquid separation of DOE tank wastes. Crossflow filtration was found to remove solids effectively, as judged by filtrate clarity and radiochemical analysis. However, results from Hanford tests suggest a need to de-complex plutonium, possibly by controlling carbonate and pH, when processing tank wastes for immobilization.

Crossflow filtration is effective for all types of tank wastes within the DOE complex and can be used to remove solids from liquids at very low solids concentrations as well as concentrate solids to relatively high solids concentrations.

APPENDIX A

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APPENDIX B

TECHNOLOGY PROCESS SCHEMATIC

Process Schematic

The cell unit filter (CUF), shown schematically in Figure B-1, was designed at the Savannah River Site and used for all testing. The slurry feed is introduced into the CUF through the slurry reservoir. A Moyno progressive-cavity pump powered by an air motor pumps the slurry from the reservoir through the magnetic flowmeter and a 0.5-in-diameter filter. The system is designed to accommodate filters of 6 in or 18 in of active filter length. In addition, different filter porosity and materials of construction may be tested.

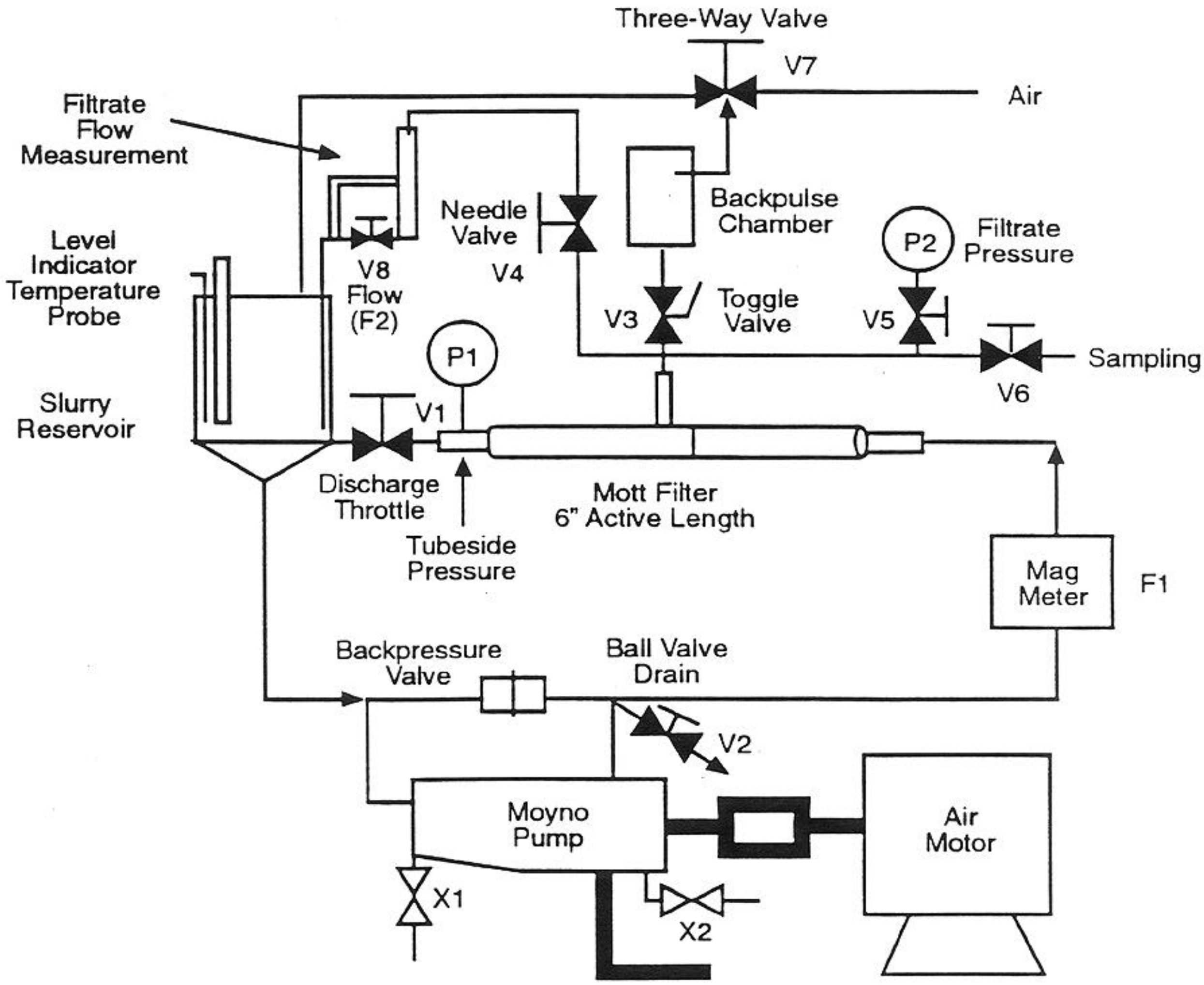

Figure B-1. Cell unit filter flow diagram.

Two filter elements were used in the testing: a 0.5-micron Mott filter and a 0.1-micron Graver filter. The axial velocity and transmembrane pressure are controlled by adjusting the pump speed and the throttle valve (V1). A back-pressure (check) valve is installed to prevent over-pressurization of the system. Filtrate passes through the filter and is reconstituted with the slurry in the slurry reservoir. The filtrate flow rate is measured by means of a fill-and-drain graduated cylinder. Filtrate samples can be taken at the sampling valve (V6). The slurry temperature is measured by a type-J thermocouple installed in a temperature well in the slurry reservoir.

Filter back-pulsing is conducted by opening the toggle valve (V3) and allows the back-pulse chamber to be filled with filtrate. The toggle valve is closed and the back-pulse chamber is pressurized with air through a three-way valve (V7). Once charged, the toggle valve is then opened, allowing the pressurized filtrate to back-pulse the filter element. After completing a run, the system is drained through valves V2, V6, X1, and X2.

APPENDIX C

ACRONYMS AND ABBREVIATIONS

CAA	Clean Air Act
CUF	cell unit filter
DST	double-shell tank
EIS	Environmental Impact Statement
HLW	high-level waste
LAW	low-activity waste
LLW	low-level waste
NEPA	National Environmental Policy Act
NTU	nephelometric turbidity unit
REDC	Radiochemical Engineering Development Center
RCRA	Resource Conservation and Recovery Act
SBA	sodium bearing waste
TRU	transuranics
WAC	Washington Administrative Code